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Campbell et al.

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(54) **VERSION VISUALIZATION**

(71) Applicant: **International Business Machines Corporation**, Armonk, NY (US)

(72) Inventors: **Christopher S. Campbell**, San Jose, CA (US); **Sechan Oh**, Stanford, CA (US); **Hovey R. Strong, Jr.**, San Jose, CA (US)

(73) Assignee: **International Business Machines Corporation**, Armonk, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 13/282,546, filed on Oct. 27, 2011, now Pat. No. 8,595,201.

(51) **Int. Cl.**
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/3023*** (2013.01); ***G06F 17/30309*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,974,254	A	10/1999	Hsu	
7,111,253	B2	9/2006	Newman	
7,725,499	B1 *	5/2010	von Lepel et al.	707/803
7,788,295	B2	8/2010	Wall et al.	
7,836,028	B1 *	11/2010	Agarwal et al.	707/695
8,112,402	B2 *	2/2012	Cucerzan et al.	707/705
8,166,049	B2 *	4/2012	Bose Rantham Prabhakara et al.	707/748
2007/0239291	A1 *	10/2007	Wayland et al.	700/83

(Continued)

FOREIGN PATENT DOCUMENTS

WO 00/08575 2/2000

OTHER PUBLICATIONS

Ball et al.; Software Visualization in the Large, IEEE Computer, vol. 29, No. 4, Apr. 1996, pp. 1-27.

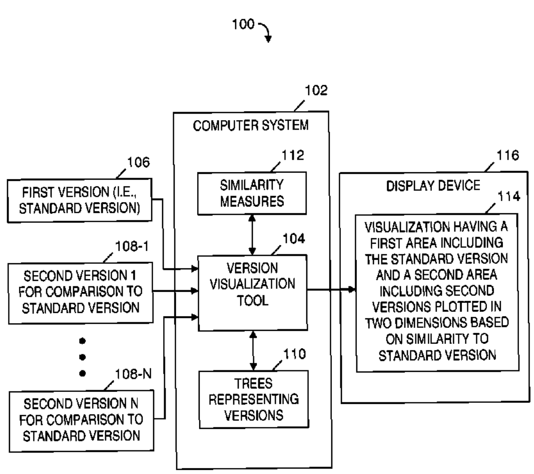
(Continued)

Primary Examiner — Sherief Badawi
Assistant Examiner — Christopher J Raab
(74) *Attorney, Agent, or Firm* — Schmeiser, Olsen & Watts

(57) **ABSTRACT**

An approach for visualizing versions of a hierarchically organized object is provided. A visualization is generated to include first and second versions including information from multiple hierarchical levels of trees representing the versions. The visualization is generated so that the second version highlights a value of a dimension for a labeled path of the tree representing the second version. The highlighted value differs from a corresponding value of a dimension for a labeled path of the tree representing the first version based on a vector space constructed to have multiple dimensions for each labeled path of the trees. A similarity measure between the first and second versions is computed by normalizing a first vector associated with the first version, normalizing a second vector associated with the second version, and determining a product of the normalized first vector and the normalized second vector.

12 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0019014	A1*	1/2009	Sugimoto	707/3
2011/0016099	A1*	1/2011	Peer et al.	707/695
2011/0099515	A1	4/2011	Doney et al.	
2011/0219012	A1*	9/2011	Yih et al.	707/749
2011/0264699	A1*	10/2011	Antonelli et al.	707/777
2011/0320445	A1*	12/2011	Lee et al.	707/737
2012/0084257	A1*	4/2012	Bansode et al.	707/638
2012/0254900	A1*	10/2012	Kumar et al.	719/328
2013/0110797	A1	5/2013	Campbell et al.	

OTHER PUBLICATIONS

Wu et al.; Visualization of Version Control Information; Thesis, University of Victoria, 2003, 116 pages.

Mladenic et al.; Visualizing Very Large Graphs Using Clustering Neighborhoods, Lecture Notes in Computer Science, 2005, v.3539/2005, 9 pages.

Anonymous; Method and System for Determining a Process Facilitator to Facilitate a Process Event, IP.com No. IPCOM000205611D, IP.com Electronic Publication: Mar. 31, 2011, Retrieved from the Internet: < URL: http://priorartdatabase.com/IPCOM/000205611>, 5 pages.

Office Action (Mail Date Dec. 27, 2012) for U.S. Appl. No. 13/282,546, filed Oct. 27, 2011.

Amendment filed Mar. 26, 2013 in response to Office Action (Mail Date Dec. 27, 2012) for U.S. Appl. No. 13/282,546, filed Oct. 27, 2011.

Notice of Allowance (Mail Date Jul. 23, 2013) for U.S. Appl. No. 13/282,546, filed Oct. 27, 2011.

* cited by examiner

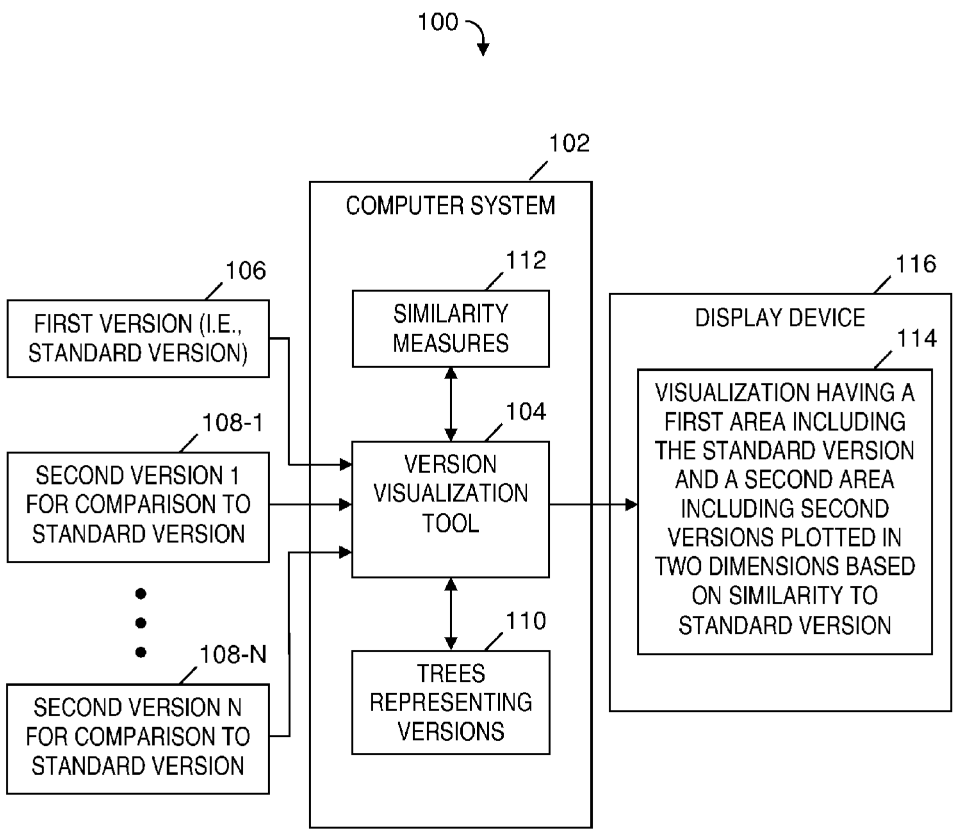

100
102
COMPUTER SYSTEM
106
FIRST VERSION (I.E., STANDARD VERSION)
112
SIMILARITY MEASURES
116
DISPLAY DEVICE
114
VISUALIZATION HAVING A FIRST AREA INCLUDING THE STANDARD VERSION AND A SECOND AREA INCLUDING SECOND VERSIONS PLOTTED IN TWO DIMENSIONS BASED ON SIMILARITY TO STANDARD VERSION
108-1
SECOND VERSION 1 FOR COMPARISON TO STANDARD VERSION
104
VERSION VISUALIZATION TOOL
108-N
SECOND VERSION N FOR COMPARISON TO STANDARD VERSION
110
TREES REPRESENTING VERSIONS

FIG. 1

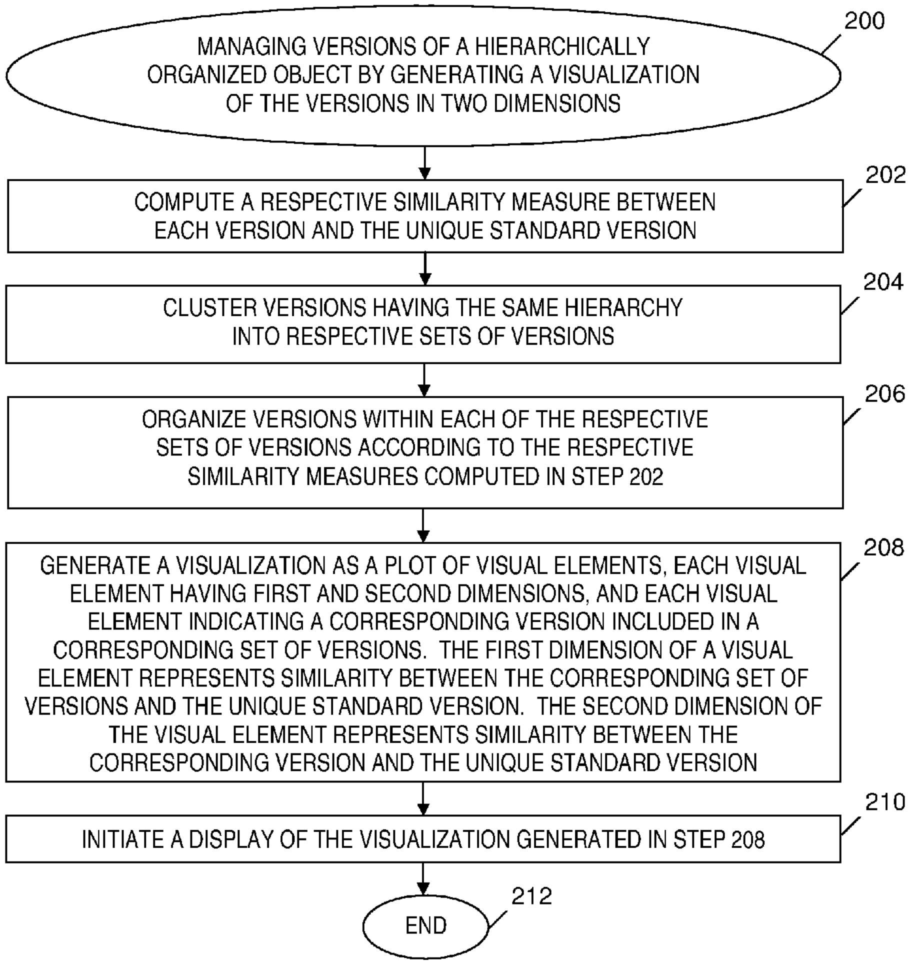

200
MANAGING VERSIONS OF A HIERARCHICALLY ORGANIZED OBJECT BY GENERATING A VISUALIZATION OF THE VERSIONS IN TWO DIMENSIONS
202
COMPUTE A RESPECTIVE SIMILARITY MEASURE BETWEEN EACH VERSION AND THE UNIQUE STANDARD VERSION
204
CLUSTER VERSIONS HAVING THE SAME HIERARCHY INTO RESPECTIVE SETS OF VERSIONS
206
ORGANIZE VERSIONS WITHIN EACH OF THE RESPECTIVE SETS OF VERSIONS ACCORDING TO THE RESPECTIVE SIMILARITY MEASURES COMPUTED IN STEP 202
208
GENERATE A VISUALIZATION AS A PLOT OF VISUAL ELEMENTS, EACH VISUAL ELEMENT HAVING FIRST AND SECOND DIMENSIONS, AND EACH VISUAL ELEMENT INDICATING A CORRESPONDING VERSION INCLUDED IN A CORRESPONDING SET OF VERSIONS. THE FIRST DIMENSION OF A VISUAL ELEMENT REPRESENTS SIMILARITY BETWEEN THE CORRESPONDING SET OF VERSIONS AND THE UNIQUE STANDARD VERSION. THE SECOND DIMENSION OF THE VISUAL ELEMENT REPRESENTS SIMILARITY BETWEEN THE CORRESPONDING VERSION AND THE UNIQUE STANDARD VERSION
210
INITIATE A DISPLAY OF THE VISUALIZATION GENERATED IN STEP 208
212
END

FIG. 2

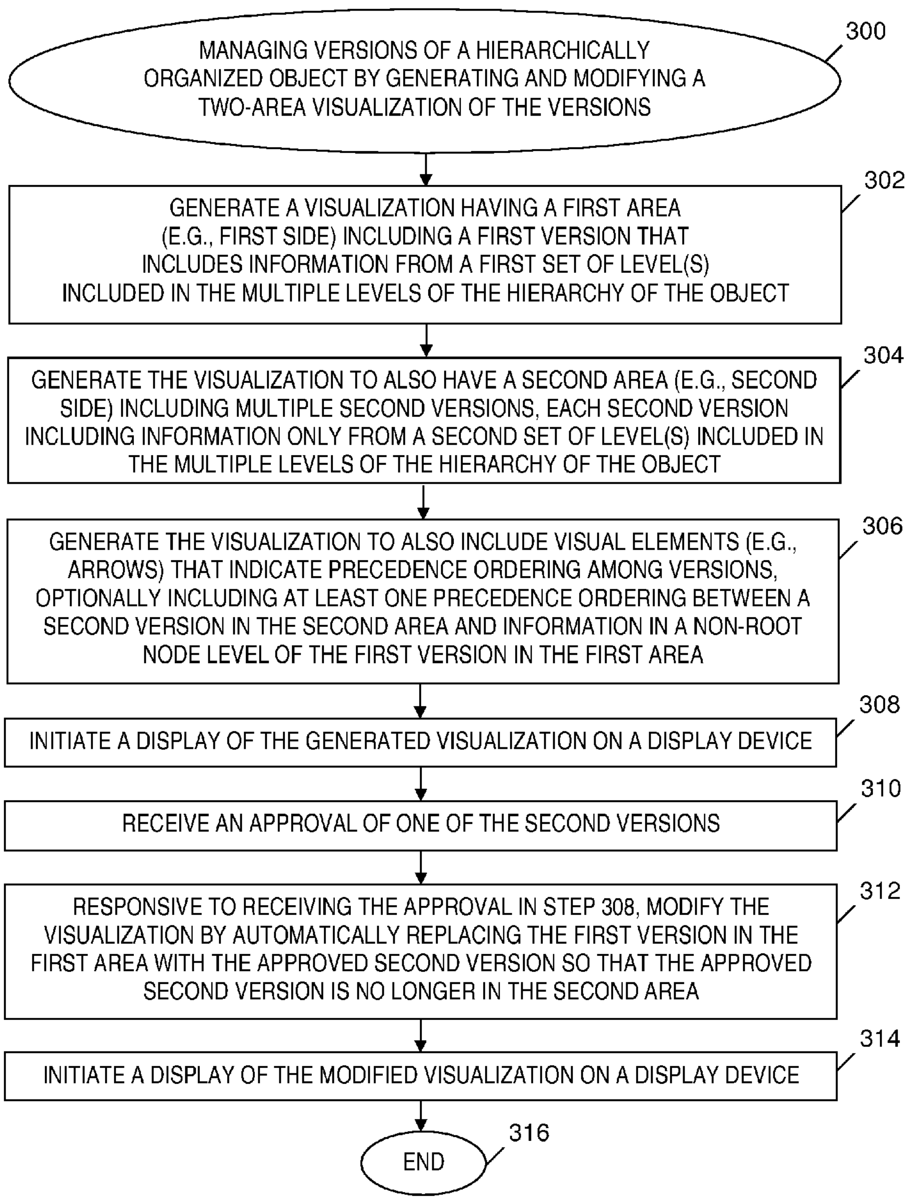

MANAGING VERSIONS OF A HIERARCHICALLY ORGANIZED OBJECT BY GENERATING AND MODIFYING A TWO-AREA VISUALIZATION OF THE VERSIONS
300
GENERATE A VISUALIZATION HAVING A FIRST AREA (E.G., FIRST SIDE) INCLUDING A FIRST VERSION THAT INCLUDES INFORMATION FROM A FIRST SET OF LEVEL(S) INCLUDED IN THE MULTIPLE LEVELS OF THE HIERARCHY OF THE OBJECT
302
GENERATE THE VISUALIZATION TO ALSO HAVE A SECOND AREA (E.G., SECOND SIDE) INCLUDING MULTIPLE SECOND VERSIONS, EACH SECOND VERSION INCLUDING INFORMATION ONLY FROM A SECOND SET OF LEVEL(S) INCLUDED IN THE MULTIPLE LEVELS OF THE HIERARCHY OF THE OBJECT
304
GENERATE THE VISUALIZATION TO ALSO INCLUDE VISUAL ELEMENTS (E.G., ARROWS) THAT INDICATE PRECEDENCE ORDERING AMONG VERSIONS, OPTIONALLY INCLUDING AT LEAST ONE PRECEDENCE ORDERING BETWEEN A SECOND VERSION IN THE SECOND AREA AND INFORMATION IN A NON-ROOT NODE LEVEL OF THE FIRST VERSION IN THE FIRST AREA
306
INITIATE A DISPLAY OF THE GENERATED VISUALIZATION ON A DISPLAY DEVICE
308
RECEIVE AN APPROVAL OF ONE OF THE SECOND VERSIONS
310
RESPONSIVE TO RECEIVING THE APPROVAL IN STEP 308, MODIFY THE VISUALIZATION BY AUTOMATICALLY REPLACING THE FIRST VERSION IN THE FIRST AREA WITH THE APPROVED SECOND VERSION SO THAT THE APPROVED SECOND VERSION IS NO LONGER IN THE SECOND AREA
312
INITIATE A DISPLAY OF THE MODIFIED VISUALIZATION ON A DISPLAY DEVICE
314
END
316

FIG. 3

400

VERSION A 11/04/28

11/05/10

- Required approvals (none)
- Completed
  - Rule: S Date: 11/04/28 By 2

	Q	D	$
• Supply Chain			
– Order entry			
▪ Accounting sl5	1	36	2.32
▪ Clerical sl3	2	36	1.8
– Approvals			
▪ Accounting sl8	2	36	18.4

FIG. 4A

450

VERSION C 11/05/05

11/05/10

- Required approvals
  - Rule: 118 Approvers {2,4,5,6}
- Completed
  - Rule: S Date: 11/04/28 By 2

	Q	D	$
• Supply Chain			
– Order entry			
▪ Accounting sl5	2	36	5.65
▪ Clerical sl3	2	36	1.8
– Approvals			
▪ Accounting sl8	1	36	9.2
• Strategy			
– Tech Forecast			
▪ Futurist sl8	1	12	4.1

FIG. 4B

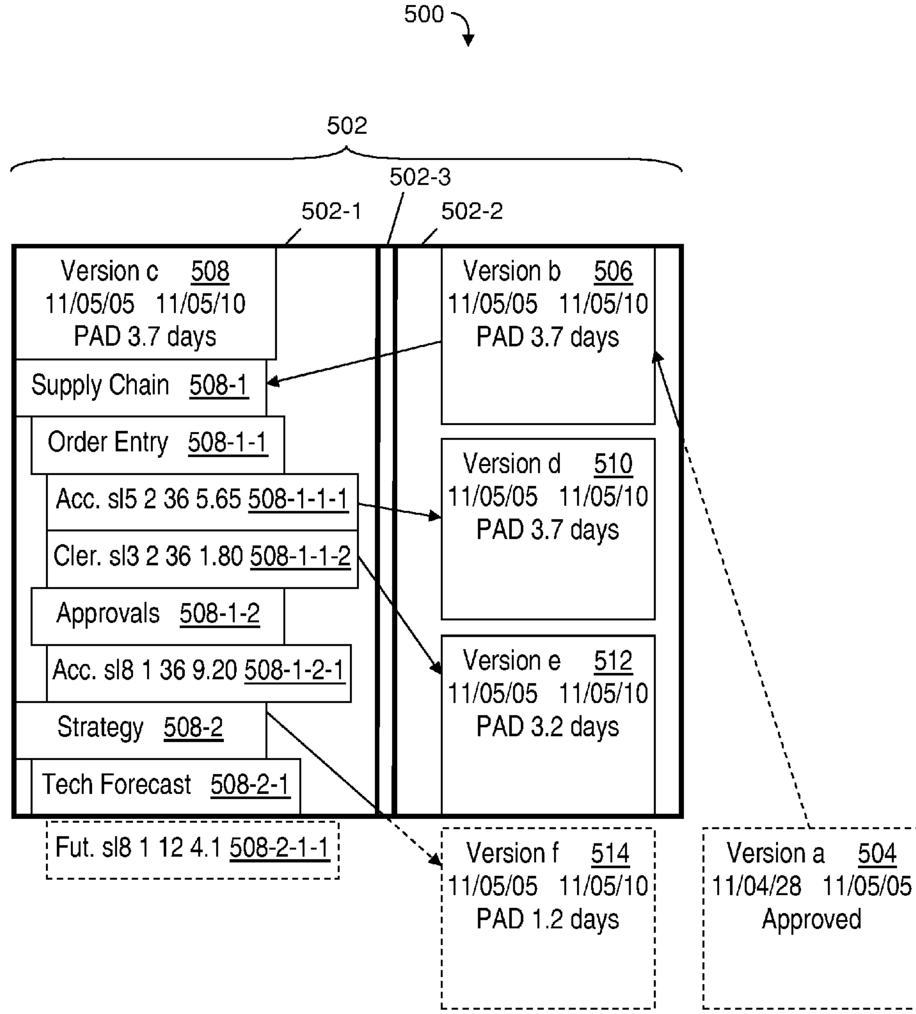

500
502
502-3
502-1
502-2
Version c 508
11/05/05 11/05/10
PAD 3.7 days
Supply Chain 508-1
Order Entry 508-1-1
Acc. sl5 2 36 5.65 508-1-1-1
Cler. sl3 2 36 1.80 508-1-1-2
Approvals 508-1-2
Acc. sl8 1 36 9.20 508-1-2-1
Strategy 508-2
Tech Forecast 508-2-1
Fut. sl8 1 12 4.1 508-2-1-1
Version b 506
11/05/05 11/05/10
PAD 3.7 days
Version d 510
11/05/05 11/05/10
PAD 3.7 days
Version e 512
11/05/05 11/05/10
PAD 3.2 days
Version f 514
11/05/05 11/05/10
PAD 1.2 days
Version a 504
11/04/28 11/05/05
Approved

FIG. 5

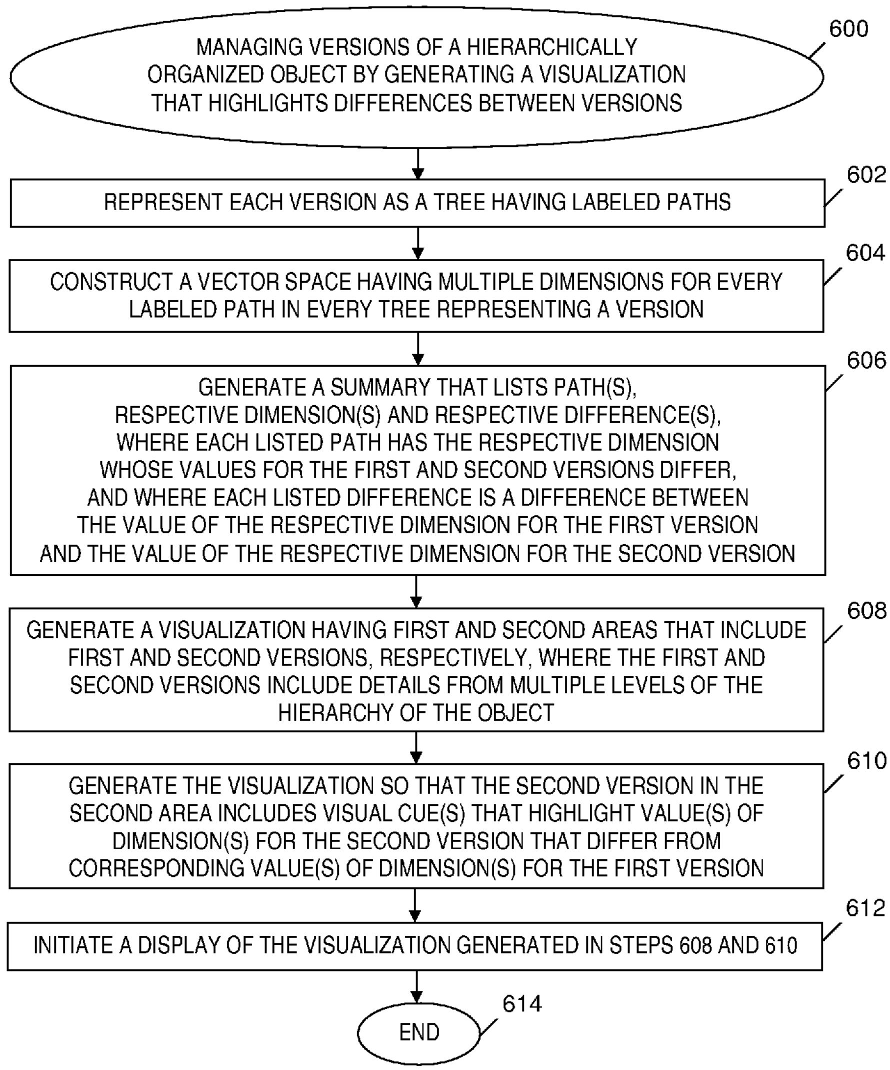

MANAGING VERSIONS OF A HIERARCHICALLY ORGANIZED OBJECT BY GENERATING A VISUALIZATION THAT HIGHLIGHTS DIFFERENCES BETWEEN VERSIONS
600
REPRESENT EACH VERSION AS A TREE HAVING LABELED PATHS
602
CONSTRUCT A VECTOR SPACE HAVING MULTIPLE DIMENSIONS FOR EVERY LABELED PATH IN EVERY TREE REPRESENTING A VERSION
604
GENERATE A SUMMARY THAT LISTS PATH(S), RESPECTIVE DIMENSION(S) AND RESPECTIVE DIFFERENCE(S), WHERE EACH LISTED PATH HAS THE RESPECTIVE DIMENSION WHOSE VALUES FOR THE FIRST AND SECOND VERSIONS DIFFER, AND WHERE EACH LISTED DIFFERENCE IS A DIFFERENCE BETWEEN THE VALUE OF THE RESPECTIVE DIMENSION FOR THE FIRST VERSION AND THE VALUE OF THE RESPECTIVE DIMENSION FOR THE SECOND VERSION
606
GENERATE A VISUALIZATION HAVING FIRST AND SECOND AREAS THAT INCLUDE FIRST AND SECOND VERSIONS, RESPECTIVELY, WHERE THE FIRST AND SECOND VERSIONS INCLUDE DETAILS FROM MULTIPLE LEVELS OF THE HIERARCHY OF THE OBJECT
608
GENERATE THE VISUALIZATION SO THAT THE SECOND VERSION IN THE SECOND AREA INCLUDES VISUAL CUE(S) THAT HIGHLIGHT VALUE(S) OF DIMENSION(S) FOR THE SECOND VERSION THAT DIFFER FROM CORRESPONDING VALUE(S) OF DIMENSION(S) FOR THE FIRST VERSION
610
INITIATE A DISPLAY OF THE VISUALIZATION GENERATED IN STEPS 608 AND 610
612
END
614

FIG. 6

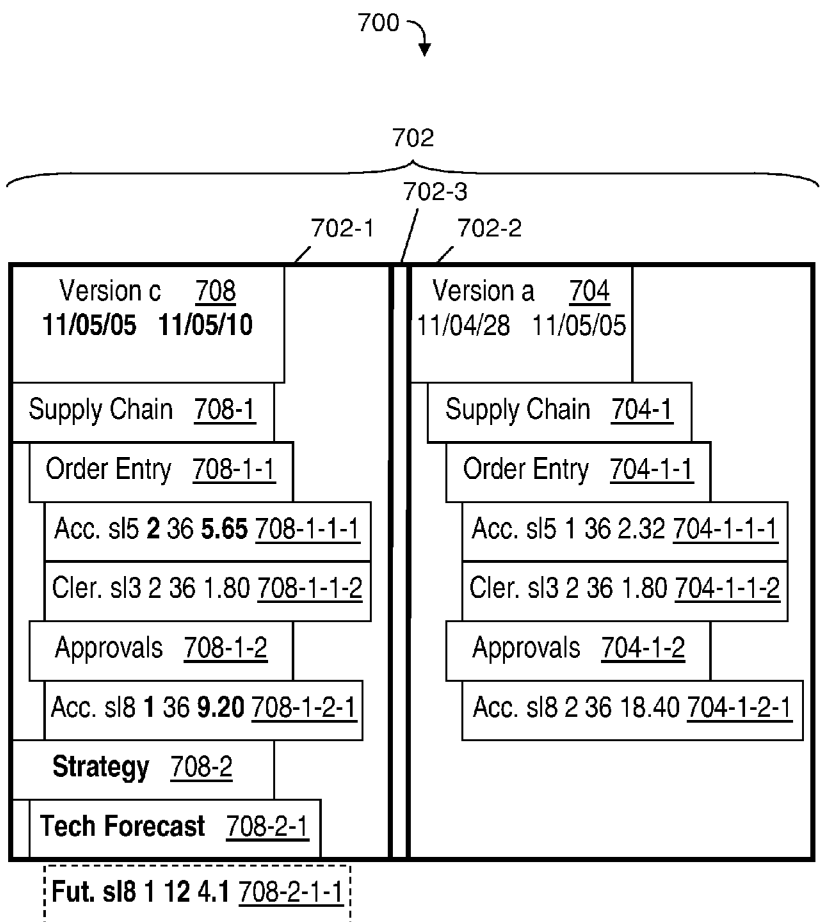

700
702
702-3
702-1
702-2
Version c 708
11/05/05 11/05/10
Supply Chain 708-1
Order Entry 708-1-1
Acc. sl5 2 36 5.65 708-1-1-1
Cler. sl3 2 36 1.80 708-1-1-2
Approvals 708-1-2
Acc. sl8 1 36 9.20 708-1-2-1
Strategy 708-2
Tech Forecast 708-2-1
Fut. sl8 1 12 4.1 708-2-1-1
Version a 704
11/04/28 11/05/05
Supply Chain 704-1
Order Entry 704-1-1
Acc. sl5 1 36 2.32 704-1-1-1
Cler. sl3 2 36 1.80 704-1-1-2
Approvals 704-1-2
Acc. sl8 2 36 18.40 704-1-2-1

FIG. 7

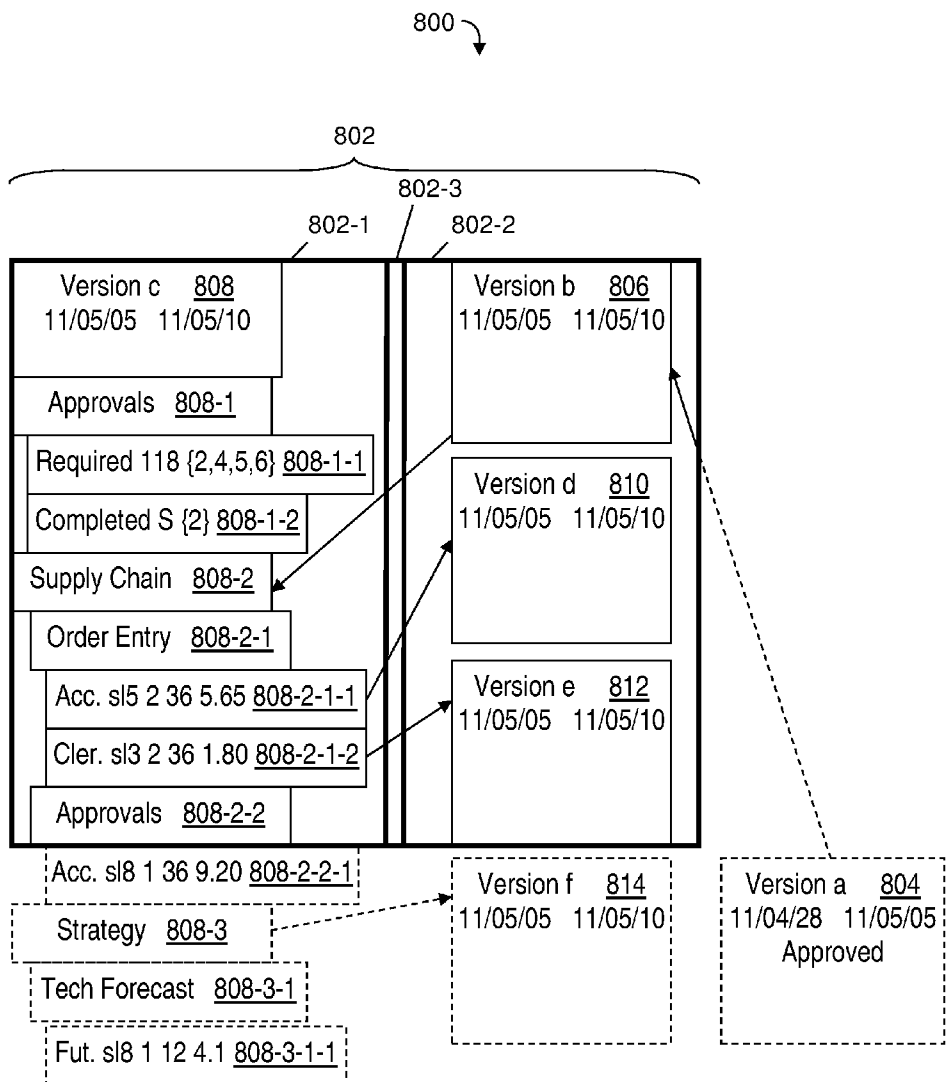
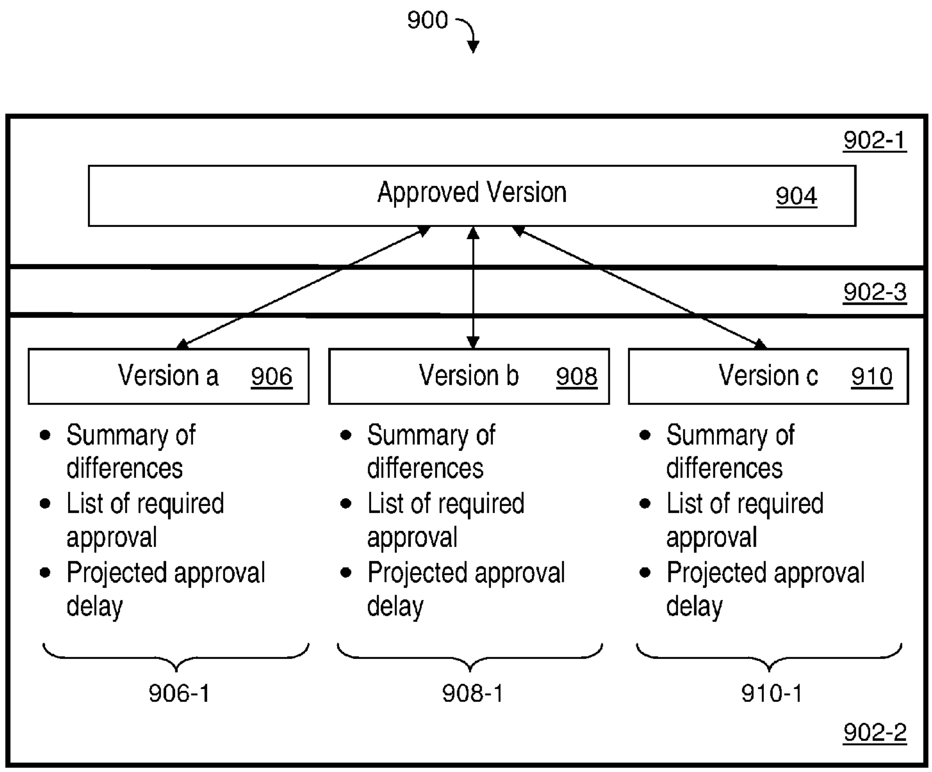

800
802
802-3
802-1
802-2
Version c 808
11/05/05 11/05/10
Approvals 808-1
Required 118 {2,4,5,6} 808-1-1
Completed S {2} 808-1-2
Supply Chain 808-2
Order Entry 808-2-1
Acc. sl5 2 36 5.65 808-2-1-1
Cler. sl3 2 36 1.80 808-2-1-2
Approvals 808-2-2
Acc. sl8 1 36 9.20 808-2-2-1
Strategy 808-3
Tech Forecast 808-3-1
Fut. sl8 1 12 4.1 808-3-1-1
Version b 806
11/05/05 11/05/10
Version d 810
11/05/05 11/05/10
Version e 812
11/05/05 11/05/10
Version f 814
11/05/05 11/05/10
Version a 804
11/04/28 11/05/05
Approved

FIG. 8



900
902-1
Approved Version
904
902-3
Version a
906
Version b
908
Version c
910
Summary of differences
List of required approval
Projected approval delay
Summary of differences
List of required approval
Projected approval delay
Summary of differences
List of required approval
Projected approval delay
906-1
908-1
910-1
902-2

FIG. 9

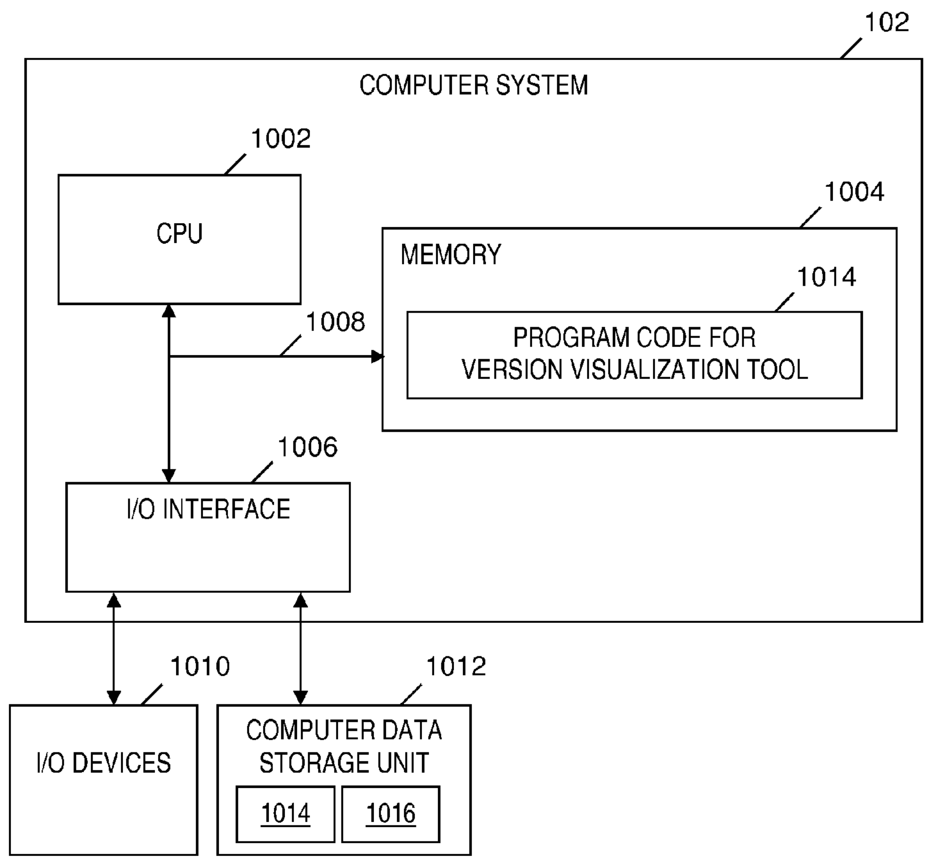

102
COMPUTER SYSTEM
1002
CPU
1004
MEMORY
1014
PROGRAM CODE FOR
VERSION VISUALIZATION TOOL
1008
1006
I/O INTERFACE
1010
1012
I/O DEVICES
COMPUTER DATA
STORAGE UNIT
1014
1016

FIG. 10

VERSION VISUALIZATION

This application is a continuation application claiming priority to Ser. No. 13/282,546 filed Oct. 27, 2011, now U.S. Pat. No. 8,595,201, issued Nov. 26, 2013.

TECHNICAL FIELD

The present invention relates to a data processing method and system for managing versions of an object, and more particularly to a technique for visualizing versions of a hierarchically organized object.

BACKGROUND

The engagement process involves a service provider and a potential service client. The engagement process begins when either the service provider or the potential service client decides to create or request a proposal for services, and continues through to a conclusion of negotiations with a result of a signed contract for the services or a decision not to pursue a contract. The service provider designates a solution preparation team. In current state-of-the-art engagement processes, the solution preparation team considers many potential proposal versions, obtains required service provider approvals for some of the versions, and releases a subset of the approved versions to the potential service client. The number and type of approvals required depends on the stage of the engagement process and on the specific service elements being proposed. Versions may be managed and saved in an ad hoc manner or in a version management system.

BRIEF SUMMARY

First embodiments of the present invention provide a method of visualizing versions of a hierarchically organized object. The object has labeled nodes and numerical parameters and the versions include a unique standard version. The method comprises the steps of:

computing a respective similarity measure between each version and the unique standard version;

clustering versions having identical hierarchies into respective sets of versions;

organizing versions within each of the respective sets of versions according to the computed respective similarity measures; and

generating a visualization as a plot having first and second dimensions, wherein the first dimension represents similarity between a set of versions and the unique standard version, and wherein the second dimension represents similarity between a version and the unique standard version.

The aforementioned steps of computing, clustering, organizing and generating are performed by at least one computer.

Second embodiments of the present invention provide a method of visualizing versions of an object organized as a hierarchy having multiple levels including (i) a root node level having a root node and (ii) one or more non-root node levels, where each of the one or more non-root node levels has one or more other nodes. The method comprises the steps of:

generating a first area of a visualization so the first area includes a first version of the object, wherein the first version includes information from the multiple levels of the hierarchy into which the object is organized;

generating a second area of the visualization so the second area includes a plurality of second versions of the object, wherein each second version includes information only from the root node level of the hierarchy;

subsequent to generating the first and second areas, receiving an approval of a second version included in the plurality of second versions; and

in response to receiving the approval of the second version, modifying the visualization by automatically replacing, in the first area, the first version with the approved second version and by removing the approved second version from the second area.

The aforementioned steps of generating the first area, generating the second area, receiving, modifying, replacing and removing are performed by at least one computer.

Systems, program products and a processes for supporting computing infrastructure where the process provides at least one support service are also described herein, where the systems, program products and processes for supporting computing infrastructure correspond to the aforementioned methods.

Embodiments of the present invention provide an automated and systematic way to group similar versions of data objects such as documents within a two-dimensional ordering of the versions and compare information in the versions in a side-by-side display. The comparison of information may include a comparison of one level of detail in a first version to a different level of detail in a second version. Embodiments disclosed herein provide a connection between version management and the approvals process. Further, embodiments of the present invention provide a systematic and automated way to view differences and summaries of differences between versions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a system for generating a visualization of versions of a hierarchically organized object, in accordance with embodiments of the present invention.

FIG. **2** is a flowchart of a process of generating a two-dimensional visualization of versions of a hierarchically organized object, where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention.

FIG. **3** is a flowchart of a process of generating and modifying a two-area visualization of versions of a hierarchically organized object, where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention.

FIG. **4**A is an example of a summary tree that represents an approved version of a hierarchically organized object, where the approved version is visualized by the system of FIG. **1**, in accordance with embodiments of the present invention.

FIG. **4**B is an example of a summary tree that represents a version of a hierarchically organized object, where the version requires approval and is visualized by the system of FIG. **1**, in accordance with embodiments of the present invention.

FIG. **5** is an example of a two-dimensional and two-area visualization of versions of a hierarchically organized object, where the visualization is generated by the process of FIG. **2** and the process of FIG. **3**, in accordance with embodiments of the present invention.

FIG. **6** is a flowchart of a process of generating a visualization of versions of a hierarchically organized object, where the visualization highlights differences between the versions, and where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention.

FIG. **7** is an example of a visualization generated by the process of FIG. **6** that highlights the differences between two versions of a hierarchically organized object, in accordance with embodiments of the present invention.

FIG. **8** is an example of a visualization generated by the process of FIG. **2** and the process of FIG. **3**, where the visualization includes a summary of approvals data for a version of a hierarchically organized object, in accordance with embodiments of the present invention.

FIG. **9** is an example of a visualization of versions of a hierarchically organized object, where the visualization is generated by the system of FIG. **1** and uses an alternate layout and an alternate level of detail for the versions, in accordance with embodiments of the present invention.

FIG. **10** is a block diagram of a computer system that is included in the system of FIG. **1** and that implements the process of FIG. **2**, the process of FIG. **3** and the process of FIG. **6**, in accordance with embodiments of the present invention.

DETAILED DESCRIPTION

Overview

Embodiments of the present invention provide an automated and systematic way to group versions of a hierarchically organized data object based on similarities across two dimensions between the grouped versions and a standard version. Embodiments of the present invention also provide an automated and systematic way to compare information of a standard version at one level of detail to information of one or more other versions at a different level of detail, where the information of the standard version is displayed in one portion (e.g., one side) of a view and the information of the one or more other versions is displayed in another portion (e.g., another side) of the view. Embodiments disclosed herein provide a connection between version management and the approvals process. Further, embodiments of the present invention provide a systematic and automated way to view differences and summaries of differences between versions. The present invention recognizes that known version management systems fail to provide the aforementioned features provided by embodiments disclosed herein.

In one embodiment, a high level visualization of proposal versions is provided to a proposal preparation team in an engagement process that utilizes a standardized catalog of service element offerings that specifies a hierarchical service element structure. The high level visualization may provide, for each version, summary financial data (e.g., projected cost), approval details (e.g., potential approvers, approver who provided approval, and date and time of the approval), projected approval delay time, and a deadline. The high level visualization may allow a selection of levels of detail at which the versions are visualized and a selection of which versions to view as a group in the visualization. The system for generating the high level visualization may be integrated with an existing system for displaying one version at a time in full detail, and with existing approvals management and version management systems.

System for Version Visualization

FIG. **1** is a block diagram of a system for generating a visualization of versions of a hierarchically organized object, in accordance with embodiments of the present invention. System **100** includes a computer system **102** that runs a software-based version visualization tool **104**. Version visualization tool **104** receives a first version **106** (a.k.a. standard version or unique standard version) and second versions **108-1** . . . **108**-N, where N>1. Each version of standard version **106** and second versions **108-1** . . . **108**-N is a version of a data object. The data object is organized in a hierarchy, where the data object has labeled nodes and numerical parameters.

Version visualization tool **104** (or another software-based tool that is not shown) generates representations of the standard version **106** and second versions **108-1** . . . **108**-N as trees **110** (i.e., hierarchically organized structures) having a root node, non-root (e.g., internal and external) nodes and labeled paths based on the hierarchy in which the aforementioned data object is organized.

Version visualization tool **104** generates similarity measures **112** that measure a respective similarity between each of the second versions **108-1** . . . **108**-N and standard version **106**. Version visualization tool utilizes trees **110** and similarity measures **112** to generate a visualization **114** and initiate a display of visualization **114** on a display device **116**. In one embodiment, visualization **114** includes a first area that includes standard version **106** and further includes a second area that includes second versions **108-1** . . . **108**-N plotted in two dimensions based on similarity measures **112**. The two dimensions in which the second versions **108-1** . . . **108**-N are plotted are discussed in more detail below relative to the discussion of FIG. **2**.

Although not shown in FIG. **1**, version visualization tool **104** may also generate a visualization that includes standard version **106** in one area and one of the second versions (e.g., second version **108-1**) in another area, with differences between the standard version and the second version highlighted with a visual cue (e.g., details in the second version **108-1** that are different from details in standard version **106** are presented in boldface).

The functionality of the components of computer system **102** is further described below relative to the discussions of FIG. **2**, FIG. **3**, FIG. **6** and FIG. **10**.

Process for Version Visualization

FIG. **2** is a flowchart of a process of generating a two-dimensional visualization of versions of a hierarchically organized object, where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention. In one embodiment, the process of FIG. **2** provides a two dimensional ordering of versions **108-1** . . . **108**-N (see FIG. **1**) based on structural similarity that determines a layout of a scrollable visualization. The process of FIG. **2** starts at step **200**. In step **202**, version visualization tool **104** (see FIG. **1**) computes a respective similarity measure between each of the second versions **108-1** . . . **108**-N (see FIG. **1**) and the unique standard version **106** (see FIG. **1**).

In step **204**, version visualization tool **104** (see FIG. **1**) clusters the second versions **108-1** . . . **108**-N (see FIG. **1**) having the same hierarchy into respective sets of versions. In one embodiment, the clustered second versions are the versions that have identical sets of paths with nonzero leaf node data in the trees that represent each of the clustered second versions.

In step **206**, based on the respective similarity measures computed in step **202**, version visualization tool **104** (see FIG. **1**) organizes the versions within each of the respective sets of versions that result from the clustering in step **204**. For example, step **206** may order the versions in the set so that the first ordered version is the most similar to standard version **106** (see FIG. **1**), the second ordered version is the next most similar to standard version **106** (see FIG. **1**), etc., until the last ordered version is the least similar to standard version **106** (see FIG. **1**).

In step **208**, version visualization tool **104** (see FIG. **1**) generates a visualization **114** (see FIG. **1**) as a plot of visual elements, each visual element having first and second dimensions (i.e., the plot is two-dimensional), and each visual element indicating a corresponding version included in a corresponding set of versions formed by the clustering in step **204**.

The first dimension of a visual element in visualization **114** (see FIG. **1**) represents similarity between the corresponding set of versions and the unique standard version **106** (see FIG. **1**). The similarity between a corresponding set of versions and the unique standard version is based on the similarity measure computed in step **202** for a particular version within the corresponding set of versions. Based on the similarity measures computed in step **202**, the aforementioned particular version is the most similar to unique standard version **106** (see FIG. **1**) as compared to any other version in the corresponding set of versions. Further, the particular version that is most similar to standard version **106** (see FIG. **1**) is determined by the organization of the versions performed in step **206**.

The second dimension of the visual element in visualization **114** (see FIG. **1**) represents similarity between the corresponding version and the unique standard version **106** (see FIG. **1**). The similarity between the corresponding version and the unique standard version **106** (see FIG. **1**) is based on the similarity measure computed in step **202** for the corresponding version.

In one embodiment, the visualization generated in step **208** includes versions within each set of versions clustered in step **204** that are ordered from left to right in a most similar to least similar order based on the measurements of similarity computed in step **202**, so that the leftmost element in an ordered set of versions is more similar to the standard version **106** (see FIG. **1**) than any other version in the ordered set of versions. That is, the aforementioned second dimension is oriented in the left to right order. The sets of versions clustered in step **204** are also ordered in the visualization in a top to bottom order by most similar leftmost element to least similar leftmost element based on the measurements of similarity computed in step **202**, so that the leftmost element of the topmost set of versions is more similar to the standard version **106** (see FIG. **1**) than any other leftmost element of any other set of versions. That is, the aforementioned first dimension is oriented in the top to bottom order.

In alternate embodiments, the orientations of the aforementioned first and second dimensions may be reversed and/or rotated. For example, the second dimension may be oriented in a top to bottom order and the first dimension may be oriented in a left to right order. As another example, the second dimension may be oriented in top to bottom order and the first dimension may be oriented in a right to left order.

In step **210**, version visualization tool **104** (see FIG. **1**) initiates a display on display device **116** (see FIG. **1**) of the visualization generated in step **208**. The process of FIG. **2** ends at step **212**.

In one embodiment, the visualization generated by the process of FIG. **2** may include parameters for each version of a proposal for providing a service, such as a projected cost, potential approvers, an approver who provided approval, a date and time of an approval, a projected approval delay time, and/or a deadline. The projected approval delay may be represented by a projected time to a decision and a projected likelihood that the proposal will be approved rather than rejected. In one embodiment, version visualization tool **104** (see FIG. **1**) retrieves historical data from a data repository coupled to computer system **102** (see FIG. **1**). The retrieved historical data indicates the time taken for approval of similar versions, where a version that is similar is based on a computed difference (as described below in the section entitled "Difference") that does not exceed a user-specified maximum difference. In one embodiment, the deadline is ignored in the computation of the difference.

FIG. **3** is a flowchart of a process of generating and modifying a two-area visualization of versions of a hierarchically organized object, where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention. In one embodiment, the process of FIG. **3** provides a two-sided visualization of that includes standard version **106** (see FIG. **1**) on a first side of the visualization at one level of detail and versions **108-1** . . . **108**-N (see FIG. **1**) on a second side of the visualization at another level of detail. In one embodiment, the process of FIG. **3** provides an automatic modification of a visualization in response to receiving an approval of a version, so that the most recently approved version replaces the standard version on the first side of the visualization.

The process of FIG. **3** starts at step **300**. In step **302**, version visualization tool **104** (see FIG. **1**) generates a visualization having a first area (e.g., a first side) including first version **106** (see FIG. **1**) of the hierarchically organized object, where the first version includes information from a first set of one or more levels included in the multiple levels of the hierarchy of the object.

In step **304**, version visualization tool **104** (see FIG. **1**) generates the visualization to also include a second area including multiple second versions **108-1** . . . **108**-N (see FIG. **1**) of the hierarchically organized object. Each of the second versions **108-1** . . . **108**-N (see FIG. **1**) includes information from a second set of one or more levels included in the multiple levels of the hierarchy of the object. In one embodiment, the second set of one or more levels is different from the first set of one or more levels described above relative to step **302**. In one embodiment, the first version includes information from multiple levels of the hierarchy of the object and each second version includes information from only the root node level of the hierarchy of the object.

In step **306**, version visualization tool **104** (see FIG. **1**) generates the visualization to also include one or more visual elements (e.g., arrows) that indicate precedence ordering among the versions **106** and **108-1** . . . **108**-N. As used herein, precedence ordering is defined as an ordering from a first version to a second version that indicates the second version is generated from a modification of the first version. In one embodiment, the generated visual element(s) includes a visual element that indicates precedence ordering between information at a root node level for second version **108-1** (see FIG. **1**) in the second area and information in a non-root node (e.g., leaf node or internal node) level for first version **106** (see FIG. **1**) in the first area.

In an alternate embodiment, Step **306** generates visual elements that indicate temporal ordering among the versions. For example, in the alternate embodiment, a generated visual element from a first version to a second version indicates that the time stamp of the first version precedes the time stamp of the second version.

When a user saves changes to a first version having a date-time stamp, a second version is created, which has a new date-time stamp. System **100** (see FIG. **1**) maintains a link from the second version to the first version to indicate the precedence ordering where the second version was generated by modifying the first version. In one embodiment, a user requests the generation of the visualization as in step **306** so that the visual elements (e.g., arrows) are displayed to indicate the precedence ordering among versions. When a version is displayed at a level that shows service elements at any level of the hierarchy, then the visual elements (e.g., arrows) are displayed to indicate which service element was changed to modify the first version to make the second version. For example, multiple arrows may start from one version and be drawn to multiple service elements. Phantom service elements may be displayed to indicate the service elements that have been removed from a first version to make the second version.

In step **308**, version visualization tool **104** (see FIG. **1**) initiates a display on display device **116** (see FIG. **1**) of the visualization generated in step **306**.

In step **310**, version visualization tool **104** (see FIG. **1**) receives an approval of one of the second versions **108-1** . . . **108**-N included in the second area of the visualization generated in step **306**.

In step **312**, responsive to the approval received in step **310**, version visualization tool **104** (see FIG. **1**) modifies the visualization by automatically replacing the first version **106** (see FIG. **1**) in the first area with the approved second version (e.g., second version **108-1** in FIG. **1**) and removes the approved second version from the second area.

In step **314**, version visualization tool **104** (see FIG. **1**) initiates a display on display device **116** (see FIG. **1**) of the visualization modified in step **312**. The process of FIG. **3** ends at step **316**.

In one embodiment, steps **310**, **312** and **314** are optional steps. In one embodiment, the process of FIG. **3** is combined with the process of FIG. **2** so that the generated visualization includes second versions **108-1** . . . **108**-N (see FIG. **1**) displayed in the two dimensions provided by the process of FIG. **2** and further includes standard version **106** (see FIG. **1**) in a first area of the visualization and the second versions **108-1** . . . **108**-N (see FIG. **1**) in the second area of the visualization.

In one embodiment, the first area is a left side of a visualization and the second area is a right side of the visualization. In alternate embodiments, the areas (e.g., sides) in which the first version and second versions are included in the visualization generated in step **306** and modified in step **312** may be reversed or rotated. For example, the first version may be included in a top area of the visualization and the second versions may be included in a bottom area of the visualization. As another example, the first version may be included on the right side of the visualization and the second versions may be included on the left side of the visualization.

As one example, standard version **106** (see FIG. **1**) and second versions **108-1** . . . **108**-N (see FIG. **1**) are versions of proposals for providing one or more services. Each proposal version is represented as a tree included in trees **110** (see FIG. **1**) each tree has labels on its edges. The root node of a tree includes the following information:

- Date-time stamp of the proposal indicating the date and time the proposal was received.
- Link to a previous version based on precedence or temporal ordering
- Deadline for completing the work required to provide the service
- Total revenue

Each node in the tree includes the following information about approval status, if needed:

- Required approvals
  - Rule
  - Potential approvers
- Completed approvals
  - Date-time approved
  - Approved by

Each leaf node in the tree includes the following information:

- Quantity of service by time unit
- Projected cost by time unit
- Projected revenue by time unit

In cost summary form, a leaf node in the tree includes the information listed below (and the root node includes no total revenue):

- Total quantity of service
- Total duration
- Total projected cost

In this example, the system tracks the approval process by recording time information regarding submissions and approvals or rejections.

FIG. **4**A is an example of a summary tree that represents an approved version of a hierarchically organized object, where the approved version is visualized by the system of FIG. **1**, in accordance with embodiments of the present invention. Summary tree **400** represents an approved version (i.e., Version A) based on an approval by an approver identified as "2" on Apr. 28, 2011 (see the line in tree **400** that includes "Completed" and "Date: Nov. 4, 1928 By 2") and based on there being no required approvals that are pending (see the line in tree **400** that includes "Required approvals (none)"). Furthermore, Summary tree **400** includes details such as a quantity of service under the column labeled "Q", a duration under the column labeled "D" and a projected cost under the column labeled "S." For example, for a proposal version represented by tree **400**, a level of detail labeled Accounting s15 is associated with a quantity of service of 1, a duration of 36 and a projected cost of 2.32 (see the line in tree **400** that includes "Accounting s15").

FIG. **4**B is an example of a summary tree that represents a version of a hierarchically organized object, where the version requires approval and is visualized by the system of FIG. **1**, in accordance with embodiments of the present invention. Summary tree **450** indicates a version (i.e., Version C) that is not yet approved based on a required approval needing to be approved by any of the approvers identified as 2, 4, 5 or 6 (see the line in tree **450** under "Required approvals" that includes "Approvers {2,4,5,6}). The version represented by tree **450** may be a modification of tree **400** (see FIG. **4**B), where the modification includes a modification of the quantity of service for Accounting s15 (i.e., the quantity of service of 1 in tree **400** in FIG. **4**A is changed to 2 in tree **450**), a modification of the projected cost for Accounting s18 (i.e., the projected cost of 18.4 in tree **400** in FIG. **4**A is changed to 9.2 in tree **450**), and an addition of a new path that is not included in tree **400** in FIG. **4**A (i.e., the path indicated by Strategy, Tech Forecast, Futurist s18 in tree **450**).

In the examples shown in FIG. **4**A and FIG. **4**B, Version A is complete and approved, but Version C requires approval from one person out of a set of four potential approvers. Version visualization tool **104** retrieves recent historical data that includes statistics regarding the approvals related performance of the four potential approvers restricted to versions whose difference to a standard version is within a user-specified maximum difference. The version visualization tool **104** (see FIG. **1**) computes a projected approval delay that is expected for Version C or, in the case in which there is insufficient historical data to make the computation, the tool **104** (see FIG. **1**) generates an indication that the approval delay is unpredictable.

Difference

In one embodiment, version visualization tool **104** (see FIG. **1**) constructs a vector space with two dimensions for every labeled path in every tree representing a version (i.e., every tree in trees **110** (see FIG. **1**)). One dimension is for a number of time units with nonzero projected cost (i.e., duration) and the other dimension is for total projected cost. To distinguish versions with distinct deadlines, a third dimension for a deadline is optionally added to the vector space for every labeled path in every tree. In one embodiment, the version visualization tool **104** (see FIG. **1**) generates the trees **110** (see FIG. **1**) and the vector space prior to step **202** in FIG. **2** and prior to step **302** in FIG. **3**.

For Version A represented by tree **400** in FIG. **4**A and for Version C represented by tree **450** in FIG. **4**B, the corresponding vectors constructed in the vector space are shown in the Version A and Version C columns of Table 1. The paths in FIG. **4**A and FIG. **4**C are indicated in abbreviated form in the Path column in Table 1. The path indicated by Supply Chain, Order Entry, Accounting s15 in FIG. **4**A and FIG. **4**B is indicated by Su.O.A.s15 in Table 1. The path indicated by Supply Chain, Order Entry, Clerical s13 in FIG. **4**A and FIG. **4**B is indicated by Su.O.C.s13 in Table 1. The path indicated by Supply Chain, Approvals, Accounting s18 in FIG. **4**A and FIG. **4**B is indicated by Su.A.A.s18 in Table 1. The path indicated by Strategy, Tech Forecast, Futurist s18 in FIG. **4**B is indicated by St.T.F.s18 in Table 1.

Values for the duration and projected cost dimensions are included in Table 1 for each path and for each version. For example, for Path Su.O.A.s15, the value for the duration dimension is 36 for both Version A and Version C, the value for the projected cost dimension is 2.32 for Version A, and the value for the projected cost dimension is 5.65 for Version C.

TABLE 1

Path	Version A	Version C
Su.O.A.sl5	36	36
	2.32	5.65
Su.O.C.sl3	36	36
	1.8	1.8
Su.A.A.sl8	36	36
	18.4	9.2
St.T.F.sl8	0	12
	0	4.1

The difference between two versions is measured by 1—cosine of the angle between the two vectors constructed from the labeled paths of the trees representing the two versions. The cosine value is also the correlation coefficient between the values in the two vectors. The aforementioned difference is the highest level summary of difference. For Version A and Version C shown in FIG. **4**A and FIG. **4**B, respectively, the cosine of the angle between the vectors shown in Table 1 is 0.94 and the difference between Version C and Version A is 0.06 (i.e., 1 —cosine or 1—0.94). Table 2 includes the values used to compute the cosine value for Version A and Version C in FIG. **4**A and FIG. **4**B, respectively.

TABLE 2

Vector Version A	A-mean of A	Square of (A-mean of A)	Norm. A	Vector Version C	C-mean of C	Square of (C-mean of C)	Norm. C	Norm. A * Norm. C
36.00	19.69	387.50	0.43	36.00	18.41	338.79	0.45	0.19
2.32	−14.00	195.86	−0.30	5.65	−11.94	142.65	−0.29	0.09
36.00	19.69	387.50	0.43	36.00	18.41	338.79	0.45	0.19
1.80	−14.52	210.69	−0.32	1.80	−15.79	249.44	−0.38	0.12
36.00	19.69	387.50	0.43	36.00	18.41	338.79	0.45	0.19
18.40	2.09	4.35	0.05	9.20	−8.39	70.46	−0.20	−0.01
0.00	−16.32	266.18	−0.36	12.00	−5.59	31.29	−0.14	0.05
0.00	−16.32	266.18	−0.36	4.10	−13.49	182.08	−0.33	0.12
Sum = 130.52		Sum = 2105.75		Sum = 140.75		Sum = 1692.29		Sum (i.e., cosine) = 0.94
Mean of A = 16.32		Sqrt of sum = 45.89		Mean of C = 17.59		Sqrt of sum = 41.14		

A more detailed summary of differences may be generated by listing each path on which there is a difference together with the amount of the difference in time units (i.e., duration) and in projected cost. The differences in the projected cost are represented algebraically by subtracting the quantity of the first version (i.e., Version A) from the quantity of the second version (i.e., Version C). If one of the quantities is zero, then the difference is represented by boldface or highlighted by another visual cue. Table 3 includes a more detailed summary of differences in duration and projected cost for Versions A and C.

TABLE 3

Path	Projected Cost or Duration	Difference between Version C and Version A
Su.O.A.sl5	Projected cost	3.33
Su.A.A.sl8	Projected cost	−9.2
St.T.F.sl8	Duration	**12**
St.T.F.sl8	Projected cost	**4.1**

In one embodiment, version visualization tool **104** (see FIG. **1**) generates a visualization including first version **106** (see FIG. **1**) and a second version (e.g., second version **108-1** in FIG. **1**) at a most detailed level. For the paths in which the tree representing the second version differs from that of the first version, the path is presented in the visualization in boldface or with another visual cue. For each path in the first version that does not appear in the second version, version visualization tool **104** (see FIG. **1**) adds a phantom path to the tree representing the second version, where the phantom path has labels and quantities distinguished by a change of font or by another visual cue.

Visualization

FIG. **5** is an example of a two-dimensional and two-area visualization of versions of a hierarchically organized object, where the visualization is generated by the process of FIG. **2** and the process of FIG. **3**, in accordance with embodiments of the present invention. Visualization **500** includes a visible viewing surface **502** of the visualization **500**. Visible viewing surface **502** includes a left side **502-1**, a right side **502-2** and an optional central gutter **502-3** between left side **502-1** and right side **502-2**. Left side **502-1** may be the first area generated in step **302** (see FIG. **3**). Right side **502-2** may be the second area generated in step **304** (see FIG. **3**). Visible viewing surface **502** does not include any rectangle, arrow or portion of an arrow that is depicted with dashed lines in FIG. **5**. For example, visible viewing surface **502** does not include rectangle **504** that represents Version a and the portion of the arrow starting from rectangle **504** and ending at the border of visible viewing surface **502**.

Visualization **500** includes rectangles **504**, **506**, **508**, **510**, **512** and **514**, which represent respective root nodes of trees representing Version a, Version b, Version c, Version d, Version e, and Version f, respectively. The PAD value included in rectangles **504**, **506**, **508**, **510**, **512** and **514** is a projected approval delay. Left side **502-1** includes a detailed view of Version c **508**, showing a detailed view of the tree representing Version c:

- Rectangles **508-1** and **508-2** (i.e., Supply Chain and Strategy, respectively) represent internal nodes connected to and at a next level down from the root node represented by rectangle **508** (i.e., Version c).
- Rectangles **508-1-1** and **508-1-2** (i.e., Order Entry and Approvals, respectively) are internal nodes that are connected to and at a next level down from the Supply Chain node **508-1**.
- Rectangle **508-2-1** (i.e., Tech Forecast) is an internal node connected to and at a next level down from the Strategy node **508-2**.
- Rectangles **508-1-1-1** and **508-1-1-2** are leaf nodes connected to and at a next level down from Order Entry node **508-1-1**.
- Rectangle **508-1-2-1** is a leaf node connected to and at a next level down from Approvals node **508-1-2**.
- Rectangle **508-2-1-1** is a leaf node connected to and at a next level down from Tech Forecast node **508-2-1**. Leaf node **508-2-1-1** is not currently visible in left side **502-1**, but may become visible in left side **502-1** by a user utilizing a scrolling feature that scrolls through the levels of the tree representing Version c. For example, a user may scroll left side **502-1** down so that rectangle **508-2-1-1** is visible.

Each of the leaf nodes visible or potentially visible in left side **502-1** indicates three values in the following order: quantity of service, duration and projected cost. For example, rectangle **508-1-1-1** represents a leaf node labeled Acc. s15 that has a quantity of service value of 2, a duration value of 36 and a projected cost value of 5.65. The similarity measures computed in step **202** (see FIG. **2**) may be cosine similarity measures that utilize, for example, the duration and projected cost values shown in the leaf nodes that are visible or are potentially visible in left side **502-1**.

Right side **502-2** includes rectangles representing root nodes of trees included in trees **110** (see FIG. **1**). The rectangles currently visible on right side **502-2** are Version b **506**, Version d **510** and Version e **512**. Via another scrolling feature that is independent of the scrolling feature for left side **502-1**, the user may scroll up or down, or left or right to make other rectangles visible in right side **502-2**. For example, a user may scroll right side **502-2** down to make Version f **514** visible and to make Version b **506** not visible in right side **502-2**. As another example, after scrolling right side **502-2** down, the user may scroll right side **502-2** to the right so that Version a **504** is visible and Version f **514** is not visible in right side **502-2**.

When visualization **500** is displayed on a display device (see step **210** in FIG. **2**, step **308** in FIG. **3** and step **314** in FIG. **3**), rectangles **508-2-1-1**, **514** and **504** are not visible in the display device, as is indicated by their dashed borders in visualization **500**.

Arrows in visualization **500** indicate precedence ordering and are generated by step **306** (see FIG. **3**). The arrow from Version b **506** to Supply Chain **508-1** indicates that Version c is a modification of Version b and the modification includes change(s) in parameter value(s) at one or more nodes below the level of Supply Chain **508-1**. The arrow from rectangle **508-1-1-1** to Version d **510** indicates that Version d is a modification of Version c and the modification includes a change in a parameter value in the leaf node represented by rectangle **508-1-1-1**. The arrow from rectangle **508-1-1-2** to Version e **512** indicates that Version e is a modification of Version c and the modification includes a change in a parameter value in the leaf node represented by rectangle **508-1-1-2**. The arrow from Strategy **508-2** to Version f **514** indicates that Version f is a modification of Version c and the modification includes change(s) in parameter value(s) at one or more nodes below the level of Strategy **508-2**.

The two dimensional ordering of Versions b, d, e, f and a in rows and columns in visualization **500** is generated in step **208** (see FIG. **2**). Because Version f **514** and Version a **504** are in the same row, the path structures of the trees representing Version f and Version a are identical. Furthermore, as compared to Version a, Version f is more similar to Version c, as indicated by Version f **514** being the leftmost element of the row that includes Version f **514** and Version a **504** in visualization **500**. The measurements of similarity of Version f to Version c and Version a to Version c are computed in step **202** (see FIG. **2**). Version f and Version a are clustered together in one row of visualization **500** in step **204** (see FIG. **2**). Version f **514** is ordered in step **206** (see FIG. **2**) as the leftmost element of the row that includes Version f **514** and Version a **504**.

Of the versions that are visible or potentially visible in right side **502-2** (i.e., Versions, b, d, e, f and a), Version b **506** is the most similar to Version c **508** (i.e., the standard version on left side **502-1**), as is indicated by Version b **506** being the leftmost element (and only element) of the topmost row of the two dimensional ordering in visualization **500**.

FIG. **6** is a flowchart of a process of generating a visualization of versions of a hierarchically organized object, where the visualization highlights differences between the versions, and where the process is implemented by the system of FIG. **1**, in accordance with embodiments of the present invention. The process of FIG. **6** starts at step **600**. In step **602**, version visualization tool **104** (see FIG. **1**) represents each version as a tree having labeled paths.

In step **604**, version visualization tool **104** (see FIG. **1**) constructs a vector space having multiple dimensions for every labeled path in every tree included in trees **110** (see FIG. **1**). In one embodiment, step **604** includes generating vectors in the vector space so that each vector has two parameters (i.e., duration and projected cost). For example, a vector space including a first vector of duration and projected cost values of dimensions of paths in a tree representing Version A (see FIG. **4**A) and a second vector of duration and projected cost values of dimensions of paths in another tree representing Version C (see FIG. **4**B) is shown in Table 1 presented above. Table 1 depicts the first vector as including the values 36, 2.32, 36, 1.8, 36, 18.4, 0 and 0, and the second vector as including the values 36, 5.65, 36, 1.8, 36, 9.2, 12 and 4.1.

In step **606**, version visualization tool **104** (see FIG. **1**) generates a summary that lists one or more paths, respective dimension(s), and respective differences(s). Each listed path has the respective dimension whose parameter values for the first and second versions differ. Each listed difference is a difference between the value of the respective dimension for the first version and the value of the respective dimension for the second version. Table 3 presented above includes an example of a summary generated in step **606**.

In step **608**, version visualization tool **104** (see FIG. **1**) generates a visualization having first and second areas (e.g., left and right sides) that include a first version and a second version, respectively, of a hierarchically organized object, where the first and second versions include details from multiple levels of the hierarchically organized object.

In step **610**, version visualization tool **104** (see FIG. **1**) generates the visualization so that that the second version in the second area includes one or more visual cues (e.g., boldface) that highlight value(s) of dimension(s) in at least one path of a tree representing the second version, where the highlighted value(s) differ from corresponding value(s) of dimension(s) in at least one path of another tree representing the first version.

In step **612**, version visualization tool **104** (see FIG. **1**) initiates a display on display device **116** (see FIG. **1**) of the visualization generated in steps **608** and **610**. The process of FIG. **6** ends at step **614**.

FIG. **7** is an example of a visualization generated by the process of FIG. **6** that highlights the differences between two versions of a hierarchically organized object, in accordance with embodiments of the present invention. Visualization **700** is an example of a visualization generated in steps **608** and **610**, and includes a visible viewing surface **702**, which has a left side **702-1**, a right side **702-2** and an optional gutter **702-3** between left side **702-1** and right side **702-2**. Left side **702-1** and right side **702-2** may be the second and first areas, respectively, generated in step **608** (see FIG. **6**). Visible viewing surface **702** does not include any rectangle that is depicted with dashed lines in FIG. **7**.

Visualization **700** includes rectangles **704** and **708**, which represent respective root nodes of trees representing Version a and Version c, respectively. Left side **702-1** includes a detailed view of the tree representing Version c. In the tree representing Version c, Supply Chain **708-1** and Strategy **708-2** are the nodes directly below and connected to root node **708**. Order Entry **708-1-1** and Approvals **708-1-2** are the nodes directly below and connected to Supply Chain node **708-1**. Tech Forecast node **708-2-1** is the node directly below and connected to Strategy node **708-2**. Leaf nodes **708-1-1-1** and **708-1-1-2** are directly below and connected to Order Entry node **708-1-1**. Leaf node **708-1-2-1** is directly below and connected to Approvals node **708-1-2**. Leaf node **708-2-1-1** is directly below and connected to Tech Forecast node **708-2-1**, and is not currently visible in left side **702-1**, but may become visible in left side **702-1** by scrolling left side **702-1** down.

Right side **702-2** includes a detailed view of the tree representing Version a, which is a most recent approved version, which is an example of standard version **106** (see FIG. **1**). In the tree representing Version a, Supply Chain **704-1** is the node directly below and connected to root node **704**. Order Entry **704-1-1** and Approvals **704-1-2** are the nodes directly below and connected to Supply Chain node **704-1**. Leaf nodes **704-1-1-1** and **704-1-1-2** are directly below and connected to Order Entry node **704-1-1**. Leaf node **704-1-2-1** is directly below and connected to Approvals node **704-1-2**.

Each of the leaf nodes visible or potentially visible in left side **702-1** or visible in right side **702-2** indicates three values in the following order: quantity of service, duration and projected cost. For example, rectangle **708-1-1-1** represents a leaf node labeled Acc. s15 that has a quantity of service value of 2, a duration value of 36 and a projected cost value of 5.65.

In one example, visualization **700** includes right side **702-2** as the first area (see step **608** in FIG. **6**), which includes a detailed view of the most recently approved version (i.e., Version a). Visualization **700** also includes left side **702-1** as the second area (see step **608** in FIG. **6**), which includes a detailed view of one of the second versions (i.e., Version c) that is being compared to the most recently approved version. The boldface values 2 and 5.65 (i.e., quantity of service and projected cost values, respectively) in leaf node Acc. s15 **708-1-1-1** indicate that Version c is a modification of Version a and the modification includes a change in the corresponding values in the corresponding leaf node in Version a. That is, the quantity of service value of 1 in leaf node Acc. s15 **704-1-1-1** is changed to 2 in corresponding leaf node Acc. s15 **708-1-1-1**. Furthermore, the projected cost value of 2.32 in leaf node Acc. s15 **704-1-1-1** is changed to 5.65 in corresponding leaf node Acc. s15 **708-1-1-1**.

The boldface values 1 and 9.20 (i.e., quantity of service and projected cost values, respectively) in leaf node Acc. s18 **708-1-2-1** indicate that Version c is a modification of Version a and the modification includes a change in the corresponding values in the corresponding leaf node in Version a. That is, the quantity of service value of 2 in leaf node Acc. s18 **704-1-2-1** is changed to 1 in corresponding leaf node Acc. s18 **708-1-2-1**. Furthermore, the projected cost value of 18.40 in leaf node Acc. s18 **704-1-2-1** is changed to 9.20 in corresponding leaf node Acc. s18 **708-1-2-1**.

Moreover, Strategy node **708-2**, Tech Forecast node **708-2-1** and leaf node Fut. s18 **708-2-1-1** are in bold to indicate that these nodes were added to Version a to generate Version c.

FIG. **8** is an example of a visualization generated by the process of FIG. **2** and the process of FIG. **3**, where the visualization includes a summary of approvals data for a version of a hierarchically organized object, in accordance with embodiments of the present invention. Visualization **800** is an example of a visualization generated in step **208** (see FIG. **2**), step **306** (see FIG. **3**) and step **312** (see FIG. **3**), and includes a visible viewing surface **802**, which has a left side **802-1**, a right side **802-2** and an optional gutter **802-3** between left side **802-1** and right side **802-2**. Left side **802-1** and right side **802-2** may be the first and second areas, respectively, generated in step **306** (see FIG. **3**). Visible viewing surface **802** does not include any rectangle, arrow or portion of an arrow that is depicted with dashed lines in FIG. **8**.

Visualization **800** includes rectangles **804**, **806**, **808**, **810**, **812** and **814**, which represent respective root nodes of trees representing Versions a, b, c, d, e and f, respectively. Left side **802-1** includes a detailed view of the tree representing Version c. In the tree representing Version c, Approvals **808-1**, Supply Chain **808-2** and Strategy **808-3** are the nodes directly below and connected to root node **808**. Required node **808-1-1** and Completed node **808-1-2** are the leaf nodes directly below and connected to Approvals node **808-1**. Order Entry **808-2-1** and Approvals **808-2-2** are the nodes directly below and connected to Supply Chain node **808-2**. Tech Forecast node **808-3-1** is the node directly below and connected to Strategy node **808-3**. Leaf nodes **808-2-1-1** and **808-2-1-2** are directly below and connected to Order Entry node **808-2-1**. Leaf node **808-2-2-1** is directly below and connected to Approvals node **808-2-2**. Leaf node **808-3-1-1** is directly below and connected to Tech Forecast node **808-3-1**. Nodes **808-2-2-1**, **808-3**, **808-3-1** and **808-3-1-1** are not currently visible in left side **802-1**, but may become visible in left side **802-1** by scrolling left side **802-1** down.

Right side **802-2** includes Version b **806**, Version d **810** and Version e **812**. If right side **802-2** is scrolled down, Version f **814** becomes visible and Version b **810** becomes not visible. If right side **802-2** is scrolled down and to the right, Version a **804** becomes visible and Versions **806**, **810**, **812** and **814** are not visible.

Visualization **800** includes arrows to indicate precedence ordering among versions a, b, c, d, e and f. For example, the arrow from Strategy node **808-3** to Version f **814** indicates that Version f is a modification of Version c and the modification includes change(s) in value(s) included in path(s) that include Strategy node **808-3**.

Each of the leaf nodes visible or potentially visible in left side **802-1** indicates three values in the following order: quantity of service, duration and projected cost. For example, rectangle **808-2-1-1** represents a leaf node labeled Acc. s15 that has a quantity of service value of 2, a duration value of 36 and a projected cost value of 5.65.

Unlike visualization **500** (see FIG. **5**), visualization **800** includes summary approval data shown in leaf nodes **808-1-1** and **808-1-2**. For example, leaf node **808-1-1** indicates a set of potential approvers (i.e., {2,4,5,6}), and leaf node **808-1-2** indicates an approver (i.e., 2) who provided an approval.

FIG. **9** is an example of a visualization of versions of a hierarchically organized object, where the visualization is generated by the system of FIG. **1** and uses an alternate layout and an alternate level of detail for the versions, in accordance with embodiments of the present invention. Visualization **900** includes an alternate top to bottom layout of areas in which versions are included. Version **900** includes a top area **902-1**, a bottom area **902-2** and a central gutter area **902-3** between top area **902-1** and bottom area **902-2**. Top area **902-1** approved version **904** and bottom area **902-2** includes Version a **906**, Version b **908** and Version c **910**. Bottom area **902-2** also includes sets of information **906-1**, **908-1** and **910-1** listed under Version a **906**, Version b **908** and Version c **910**, respectively. Each set of information includes a summary of differences between values in corresponding paths in the version in bottom area **902-2** and the approved version **904**. Each set of information also includes a list of required approvals and a projected approval delay.

In visualization **900**, the approved version may be standard version **106** (see FIG. **1**). Unlike visualization **500** (see FIG. **5**), visualization **900** includes information only at a root node level for the standard version (i.e., approved version **904**), and the second versions being compared to the standard version (i.e., Versions **906**, **908** and **910**) are shown at more levels of detail than the standard version.

Computer System

FIG. **10** is a block diagram of a computer system that is included in the system of FIG. **1** and that implements the process of FIG. **2**, the process of FIG. **3** and the process of FIG. **6**, in accordance with embodiments of the present invention. Computer system **102** generally comprises a central processing unit (CPU) **1002**, a memory **1004**, an input/output (I/O) interface **1006**, and a bus **1008**. Further, computer system **102** is coupled to I/O devices **1010** and a computer data storage unit **1012**. CPU **1002** performs computation and control functions of computer system **102**, including carrying out instructions included in program code **1014** to perform a method of visualizing versions of a hierarchically organized object, where the instructions are carried out by CPU **1002** via memory **1004**. CPU **1002** may comprise a single processing unit, or be distributed across one or more processing units in one or more locations (e.g., on a client and server). In one embodiment, program code **1014** includes code for version visualization tool **104** (see FIG. **1**).

Memory **1004** may comprise any known computer-readable storage medium, which is described below. In one embodiment, cache memory elements of memory **1004** provide temporary storage of at least some program code (e.g., program code **1014**) in order to reduce the number of times code must be retrieved from bulk storage while instructions of the program code are carried out. Moreover, similar to CPU **1002**, memory **1004** may reside at a single physical location, comprising one or more types of data storage, or be distributed across a plurality of physical systems in various forms. Further, memory **1004** can include data distributed across, for example, a local area network (LAN) or a wide area network (WAN).

I/O interface **1006** comprises any system for exchanging information to or from an external source. I/O devices **1010** comprise any known type of external device, including a display device (e.g., monitor), keyboard, mouse, printer, speakers, handheld device, facsimile, etc. Bus **1008** provides a communication link between each of the components in computer system **102**, and may comprise any type of transmission link, including electrical, optical, wireless, etc.

I/O interface **1006** also allows computer system **102** to store information (e.g., data or program instructions such as program code **1014**) on and retrieve the information from computer data storage unit **1012** and/or another computer data storage unit (not shown) coupled to computer system **102**. Computer data storage unit **1012** may comprise any known computer-readable storage medium, which is described below. For example, computer data storage unit **1012** may be a non-volatile data storage device, such as a magnetic disk drive (i.e., hard disk drive) or an optical disc drive (e.g., a CD-ROM drive which receives a CD-ROM disk).

Memory **1004** and/or storage unit **1012** may store computer program code **1014** that includes instructions that are carried out by CPU **1002** via memory **1004** to visualize versions of a hierarchically organized object. Although FIG. **10** depicts memory **1004** as including program code **1014**, the present invention contemplates embodiments in which memory **1004** does not include all of code **1014** simultaneously, but instead at one time includes only a portion of code **1014**.

Further, memory **1004** may include other systems not shown in FIG. **10**, such as an operating system (e.g., Linux) that runs on CPU **1002** and provides control of various components within and/or connected to computer system **102**.

Storage unit **1012** and/or one or more other computer data storage units (not shown) that are coupled to computer system **102** may store standard version **106** (see FIG. **1**), second versions **108-1** . . . **108**-N (see FIG. **1**), similarity measures **112** (see FIG. **1**) and trees **110** (see FIG. **1**).

As will be appreciated by one skilled in the art, the present invention may be embodied as a system, method or computer program product. Accordingly, an aspect of an embodiment of the present invention may take the form of an entirely hardware aspect, an entirely software aspect (including firmware, resident software, micro-code, etc.) or an aspect combining software and hardware aspects that may all generally be referred to herein as a "module". Furthermore, an embodiment of the present invention may take the form of a computer program product embodied in one or more computer-readable medium(s) (e.g., memory **1004** and/or computer data storage unit **1012**) having computer-readable program code (e.g., program code **1014**) embodied or stored thereon.

Any combination of one or more computer-readable mediums (e.g., memory **1004** and computer data storage unit **1012**) may be utilized. The computer readable medium may be a computer-readable signal medium or a computer-readable storage medium. In one embodiment, the computer-readable storage medium is a computer-readable storage device or computer-readable storage apparatus. A computer-readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, or semiconductor system, apparatus, device or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer-readable storage medium includes: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer-readable storage medium may be a tangible medium that can contain or store a program (e.g., program **1014**) for use by or in connection with a system, apparatus, or device for carrying out instructions. Each of the terms "computer-readable storage medium" and "computer-readable, tangible storage device," as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

A computer readable signal medium may include a propagated data signal with computer-readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electromagnetic, optical, or any suitable combination thereof. A computer-readable signal medium may be any computer-readable medium that is not a computer-readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with a system, apparatus, or device for carrying out instructions.

Program code (e.g., program code **1014**) embodied on a computer-readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

Computer program code (e.g., program code **1014**) for carrying out operations for aspects of the present invention may be written in any combination of one or more programming languages, including an object oriented programming language such as Java®, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. Instructions of the program code may be carried out entirely on a user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server, where the aforementioned user's computer, remote computer and server may be, for example, computer system **102** or another computer system (not shown) having components analogous to the components of computer system **102** included in FIG. **10**. In the latter scenario, the remote computer may be connected to the user's computer through any type of network (not shown), including a LAN or a WAN, or the connection may be made to an external computer (e.g., through the Internet using an Internet Service Provider).

Aspects of the present invention are described herein with reference to flowchart illustrations (e.g., FIG. **2**, FIG. **3** or FIG. **6**) and/or block diagrams of methods, apparatus (systems) (e.g., FIG. **1** and FIG. **10**), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions (e.g., program code **1014**). These computer program instructions may be provided to one or more hardware processors (e.g., CPU **1002**) of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which are carried out via the processor(s) of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable medium (e.g., memory **1004** or computer data storage unit **1012**) that can direct a computer (e.g., computer system **102**), other programmable data processing apparatus, or other devices to function in a particular manner, such that the instructions (e.g., program **1014**) stored in the computer-readable medium produce an article of manufacture including instructions which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer (e.g., computer system **102**), other programmable data processing apparatus, or other devices to cause a series of operational steps to be performed on the computer, other programmable apparatus, or other devices to produce a computer implemented process such that the instructions (e.g., program **1014**) which are carried out on the computer, other programmable apparatus, or other devices provide processes for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

Any of the components of an embodiment of the present invention can be deployed, managed, serviced, etc. by a service provider that offers to deploy or integrate computing infrastructure with respect to visualizing versions of a hierarchically organized object. Thus, an embodiment of the present invention discloses a process for supporting computer infrastructure, wherein the process comprises providing at least one support service for at least one of integrating, hosting, maintaining and deploying computer-readable code (e.g., program code **1014**) in a computer system (e.g., computer system **102**) comprising one or more processors (e.g., CPU **1002**), wherein the processor(s) carry out instructions contained in the code causing the computer system to visualize versions of a hierarchically organized object.

In another embodiment, the invention provides a method that performs the process steps of the invention on a subscription, advertising and/or fee basis. That is, a service provider, such as a Solution Integrator, can offer to create, maintain, support, etc. a process of visualizing versions of a hierarchically organized object. In this case, the service provider can create, maintain, support, etc. a computer infrastructure that performs the process steps of the invention for one or more customers. In return, the service provider can receive payment from the customer(s) under a subscription and/or fee agreement, and/or the service provider can receive payment from the sale of advertising content to one or more third parties.

The flowcharts in FIG. **2**, FIG. **3** and FIG. **6** and the block diagrams in FIG. **1** and FIG. **10** illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code (e.g., program code **1014**), which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be performed substantially concurrently, or the blocks may sometimes be performed in reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

While embodiments of the present invention have been described herein for purposes of illustration, many modifications and changes will become apparent to those skilled in the art. Accordingly, the appended claims are intended to encompass all such modifications and changes as fall within the true spirit and scope of this invention.

The invention claimed is:

1. A method of visualizing versions of a hierarchically organized object, the method comprising the steps of:

computing a respective similarity measure between each version and a unique standard version;

clustering versions having identical hierarchies into respective sets of versions;

organizing versions within each of the respective sets of versions according to the computed respective similarity measures;

representing each version as a respective tree having labeled paths;

constructing a vector space having multiple dimensions for each labeled path of every tree, wherein the step of constructing the vector space includes constructing each vector in the vector space to have first and second parameters for each respective labeled path, wherein the first parameter indicates a duration for completing work associated with a service and a respective labeled path, wherein the second parameter indicates a cost of providing the work, and wherein the object is a document that indicates a proposal for a service provider to provide the service to a client;

generating a visualization having first and second areas that include first and second versions, respectively, wherein the first and second versions each include information from multiple levels of the respective trees; and

generating the visualization so that the second version in the second area includes a visual cue that highlights a value of a dimension for a labeled path of the respective tree representing the second version, wherein based on the constructed vector space, the highlighted value differs from a corresponding value of a dimension for a labeled path of the respective tree representing the first version,

wherein the step of computing the respective similarity measure includes computing the respective similarity measure between the first and second versions by normalizing a first vector associated with the first version, normalizing a second vector associated with the second version, and determining a product of the normalized first vector and the normalized second vector based on the first parameter indicating the duration and the second parameter indicating the cost, and

wherein the steps of computing, clustering, organizing, representing, constructing, generating the visualization having first and second areas, and generating the visualization so that the second version in the second area includes the visual cue are performed by at least one computer.

2. The method of claim **1**, further comprising the step of generating a second visualization as a plot having first and second dimensions, wherein the first dimension represents similarity between a set of versions and the unique standard version, wherein the second dimension represents similarity between a version and the unique standard version, and wherein the step of generating the second visualization is performed by the at least one computer.

3. The method of claim **1**, wherein the step of generating the second visualization includes generating the second visualization in a scrollable map in which a first portion of the second visualization is visible and a second portion of the second visualization is not visible.

4. The method of claim **1**, wherein the step of computing the respective similarity measure includes calculating a respective cosine similarity between each version and the unique standard version.

5. The method of claim **1**, further comprising the step of retrieving historical approval delay times for versions whose similarity to a version satisfies a user-specified criterion, wherein the numerical parameters include a projected time to a decision about whether to approve the version and a projected likelihood of the decision indicating an approval of the version based on the retrieved historical approval delay times, and wherein the step of retrieving is performed by the at least one computer.

6. The method of claim **1**, further comprising the step of generating a summary that lists one or more labeled paths, one or more respective dimensions and one or more respective differences, wherein each listed path includes a respective dimension whose values for the first and second versions differ based on the constructed vector space, wherein each listed respective difference indicates how much the values of the respective dimension for the first and second versions differ, and wherein the step of generating the summary is performed by the at least one computer.

7. A computer program product, comprising:

a computer-readable, tangible storage device; and

a computer-readable program code stored in the computer-readable, tangible storage device, the computer-readable program code containing instructions that are executed by a central processing unit (CPU) of a computer system to implement a method of visualizing versions of a hierarchically organized object, the method comprising the steps of:

computing a respective similarity measure between each version and a unique standard version;

clustering versions having identical hierarchies into respective sets of versions;

organizing versions within each of the respective sets of versions according to the computed respective similarity measures;

representing each version as a respective tree having labeled paths;

constructing a vector space having multiple dimensions for each labeled path of every tree, wherein the step of constructing the vector space includes constructing each vector in the vector space to have first and second parameters for each respective labeled path, wherein the first parameter indicates a duration for completing work associated with a service and a respective labeled path, wherein the second parameter indicates a cost of providing the work, and wherein the object is a document that indicates a proposal for a service provider to provide the service to a client;

generating a visualization having first and second areas that include first and second versions, respectively, wherein the first and second versions each include information from multiple levels of the respective trees; and generating the visualization so that the second version in the second area includes a visual cue that highlights a value of a dimension for a labeled path of the respective tree representing the second version, wherein based on the constructed vector space, the highlighted value differs from a corresponding value of a dimension for a labeled path of the respective tree representing the first version,

wherein the step of computing the respective similarity measure includes computing the respective similarity measure between the first and second versions by normalizing a first vector associated with the first version, normalizing a second vector associated with the second version, and determining a product of the normalized first vector and the normalized second vector based on the first parameter indicating the duration and the second parameter indicating the cost.

8. The program product of claim **7**, wherein the method further comprises the step of generating a second visualization as a plot having first and second dimensions, wherein the first dimension represents similarity between a set of versions and the unique standard version, and wherein the second dimension represents similarity between a version and the unique standard version.

9. The program product of claim **7**, wherein the step of generating the second visualization includes generating the second visualization in a scrollable map in which a first portion of the second visualization is visible and a second portion of the second visualization is not visible.

10. The program product of claim **7**, wherein the step of computing the respective similarity measure includes calculating a respective cosine similarity between each version and the unique standard version.

11. The program product of claim **7**, wherein the method further comprises the step of retrieving historical approval delay times for versions whose similarity to a version satisfies a user-specified criterion, wherein the numerical parameters include a projected time to a decision about whether to approve the version and a projected likelihood of the decision indicating an approval of the version based on the retrieved historical approval delay times.

12. The program product of claim **7**, wherein the method further comprises the step of generating a summary that lists one or more labeled paths, one or more respective dimensions and one or more respective differences, wherein each listed path includes a respective dimension whose values for the first and second versions differ based on the constructed vector space, and wherein each listed respective difference indicates how much the values of the respective dimension for the first and second versions differ.

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